The Journal of Animal & Plant Sciences, 26(1): 2016, Page: 177-184
ISSN: 1018-7081

PLANTATION METHODS EFFECTS ON COMMON VALERIAN (*VALERIANA OFFICINALIS*) YIELD AND QUALITY

J. Wiśniewski, M. Szczepanik, B. Kołodziej* and B. Król

Department of Industrial and Medicinal Plants, Agrobioengineering Faculty, University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, Poland
*Corresponding author e-mail: barbara.kolodziej@up.lublin.pl

ABSTRACT

The study aimed at determination of the optimum conditions for high yielding and high quality of *Valeriana officinalis* L. production by selecting the best variety and plantation establishment method. A higher content of active substances but lower yields of underground parts of plants were obtained in a thin-rooted variety (‘Polka’) culture, whereas an adverse tendency was observed in a thick-rooted cultivar (‘Lubelski’). Raw material from plants produced by direct seeding was characterised by a higher content of active substances and, despite lower yields, it should be recommended in high quality valerian culture. Plants grown from the seedlings produced higher yields; however, their quality expressed by the content of valerenic acid (VA) was lower. The highest yield was obtained from seedlings planted in autumn (with a satisfactory content of VA) and therefore the method could be used for valerian plantation establishment. A positive correlation was found between the content of essential oils and VA; hence, varieties with higher essential oil accumulation should be chosen for commercial cultivation of this species. Greater accumulation of VA and essential oils was observed in dried roots separated from the underground parts of the plants prior to drying in comparison to the rhizomes.

Key words: essential oil, variety, seedbed, sowing, multi-cell trays, valerenic acid.

INTRODUCTION

Common valerian (*Valeriana officinalis* L.) is a perennial medicinal plant with a long proven history of efficacy. It is cultivated on a commercial scale in northern Europe, America, and lately in Australia. It is the fourth best selling medicinal herb in Europe with retail sales of US$ 200 million (Wills and Shohet, 2003). This species has vigorous underground rhizomes producing numerous cylindrical roots (Pop *et al*., 2010), which are used medicinally for their sedative properties with indications including nervous tension, insomnia, anxiety, and stress (Fernández *et al*., 2004; Circosta *et al*., 2007; Patoka and Jakl, 2010). It is also used in the treatment of hypertension and cardiac arrhythmia (Patoka and Jakl, 2010). The important determinant of quality in valerian raw material is the concentration of active constituents that impart a health benefit to consumers. While there is still some debate on the relative effectiveness of various classes of compounds, it is widely accepted that the valerenic acid (contained in its essential oil) is the most important biologically active component and there is substantial industrial interest in increasing the level of this compound in valerian raw material. Essential oil is located in the hypodermis in large thin-walled cells at the periphery of roots and rhizomes. Valerian raw material is also rich in valepotriates, alkaloids, caffeic acid derivatives, flavonoids, lignans, and amino acids (Circosta *et al*., 2007). However, Wills and Shohet (2003) reported that the quality of rootlets and that of the crown (rhizomes) differ.

However, many valerian producers meet difficulties in fulfilment of the high requirements of pharmaceutical industry especially as regards the high content of active substances. Therefore, research should be conducted not only to indicate the best yielding variety, at the same time having a satisfactory content of active substances, but also to determine the principles of growing thereof, including identification of the best method of plantation establishment, which determines high quality of raw material. In Poland (one of the greatest valerian producers), the species is usually propagated by sowing seeds in seedbeds and followed by transplantation of the seedlings into the field (Kołodziej, 2010). There are no reports in literature about establishment of valerian plantations based on direct seed sowing in the field or production of seedlings in a greenhouse with the use of polypropylene multi-cell trays. The latter method ensures even distribution of plants, better access to light, more favourable humidity conditions, and reduced risk of root damage at transplantation. Consequently, the yields of plants propagated with this method are by ca. 15% higher than those obtained from seedlings grown in a seedbed (Kołodziej and Najda, 2007).

The aim of the study was to select the most suitable common valerian variety (from thin- and thick-rooted) and evaluate the effects of the plantation establishment method on the development of underground parts (roots and rhizomes), yields, and essential oil and valerenic acid content (in roots and rhizomes) as markers of raw material quality.

MATERIALS AND METHODS

The results of the study were obtained in a three-year field experiment conducted on experimental fields at the University of Life Sciences in Lublin (51°29′28″ N, 22°51′18″ E) on brown soil of loamy sand origin. The soil was characterised by medium humus (1.19%) and magnesium (51 mg $kg^{-1}$of soil) contents, high phosphorus (141 mg kg^{-1} of soil) and potassium (154 mg kg^{-1} of soil) contents, and neutral reaction (6.7 pH in 1 mol dm^{-3} KCl). Mineral fertilization was applied at the rates of 30 N (in a form of ammonium sulphate 34% N, incorporated in two equal doses before plantation and at full vegetation period), 22 P (in a form of single superphosphate 19% P_2O_5, applied before plantation), and 40 K kg ha^{-1} (in a form of potassium salt 60% K_2O, applied before plantation establishment). Seeds of two cultivars 'Lubelski' and 'Polka' (provided by Institute of Natural Fibres and Medicinal Plants in Poznań), commonly cultivated in Poland, were used in the experiment. The choice of these two varieties was justified by the fact that *Valeriana officinalis* is a species with different morphological characteristics, which involves differences not only in anatomy but also in accumulation of active substances. The former variety - 'Lubelski' (thick-rooted) is characterised by a larger diameter of roots, facilitating removal of soil from around the roots during the harvest, while the latter one -'Polka' (thin-rooted) produces a great number of thin roots, easily breaking down and difficult to clean from soil and impurities.

The following methods of plantation were compared: 1) sowing seeds directly in the field (autumn and spring); 2) planting seedlings obtained in a seedbed (autumn and spring); 3) planting seedlings produced in multi-cell propagation trays (spring). The field experiments were carried out in a randomized block design in four replications on plots of 15 m^2 (plants were distributed in 50 × 30 cm spacing). Direct seed sowing in the field was done with the use of a small, single-row garden seeder. Seeds were sown in the last ten days of September in autumn and in mid-April in spring. Five g of seeds were sown on each plot and, after emergence, the plants were thinned to the desired number. In order to produce seedlings, the seeds were sown on finely prepared seedbed soil in rows 15 cm apart. The seeds were sown in the last ten days of August, and later the seedlings were transplanted into respective plots in the field in autumn (the first ten days of October) and in spring (the first ten days of April). Peat moss was the substrate for seedlings produced in multi-cell trays (cell dimension 4 × 4 × 6 cm). Seeds were sown in the first ten days of March (2-3 seeds per cell) and kept in an unheated greenhouse. After emergence, one plant per cell was left for further growth. At the phase of 3-4 leaves (mid-April), they were transplanted into the field along with substrate clods. Annually the forecrop was a white mustard (as a green manure) and the land was prepared with a 28-30 cm deep plowing. After plowing, the soil was worked with the disc harrow. Harrowing was meant to destroy weeds and maintain moisture in the soil. Seedbed was prepared a few days before sowing in aggregate harrow disc harrow with adjustable corner. During vegetation a routine treatment of manual weeding, mechanical hoeing and a single spray with Fastac 100 EC (a.s.: cypermethrin, BASF SE, Germany, 0,18 l ha^{-1}) were ensured as recommended in Grower's manual (Kołodziej 2010).

The plants were harvested in the first ten days of October and the number of roots, their diameter, as well as the weight of roots and rhizomes was determined of 40 plants from each object and than they were dried in a drying chamber at 35°C. Raw material samples were analysed for the content of essential oil after hydrodistillation in Deryng's apparatus (European Pharmacopoeia, 2006) and valerenic acid by a modified HPLC method acc. to Bos *et al.* (1996) (separately in three replications for the rhizome and roots fractions). The HPLC conditions were as follows: RP Luna C_{18} column (5 µm, 250 × 4.6 mm, Phenomenex); solvent system: A: water: acetonitrile: phosphoric acid (80:20:0.05), B – water: acetonitrile: phosphoric acid (20:80:0.05), flow rate: 1 ml min^{-1}; injection volume: 20 µl; DAD condition: 220 nm. The weather conditions prevailing during the valerian vegetation period based on data from Agrometeorological Observatory of University of Life Sciences in Lublin are presented at the Figure 1.

Data were analysed with the SAS general linear model procedure (version 8.2 SAS Institute, Cary, USA). The significance of mean effects and interactions of all variables was calculated using ANOVA analysis of variance. When the statistical test revealed significant differences, the least significant Fisher's test was used to separate the means. Pearson's correlation test was applied to investigate the relationship between the most important data points reported in this study.

RESULTS

Characteristics and yield of underground parts of plants: The size and number of valerian roots were modified by the experimental factors under study. The number of roots ranged between 109 and 154, and their diameter between 2.8 and 3.8 mm (Table 1). Generally, the thick-rooted variety ('Lubelski') produced a significantly smaller number of longer roots with a higher diameter than the thin-rooted cultivar ('Polka'). However, the reaction of the varieties to the different establishment methods was almost the same. In the objects with seedlings, plants produced a higher number of roots that were thicker than those of plants derived from direct seeding (particularly in spring). On the plots with plants grown from seedlings, a similar number of roots were produced by plants grown in the multi-cell trays as well as plants from the seedbed transplanted in autumn, while a significantly lesser number of thinner roots were recorded in the traditionally produced seedlings transplanted in spring (Table 1). Weather conditions exerted a considerable effect on the discussed traits. With its high air temperatures and the highest precipitation rates during the growing season, 2010 was the most favourable year. The lowest number of roots with small diameter (with the exception of plants obtained from the multi-cell trays) was recorded in 2011, when scarce precipitation were accompanied with low temperatures.

As in the case of the above-mentioned features of the underground parts of valerian plants, significantly (over twice) higher weight of air-dry roots and rhizomes per plant was obtained when seedlings were used rather than direct seeding into the ground (Table 2). The highest values of this trait were reported in plants propagated as seedlings and transplanted in autumn as well as multi-cell tray seedlings planted in spring; in turn, the lowest values were obtained from plants originating from direct seeding in spring. The roots constituted a major part in the entire underground parts of valerian (approximately above 80%). The genetic factor also modified the development of valerian rhizomes and roots. Plants of the thick-rooted ‘Lubelski’ variety exhibited the highest weight of underground parts (Table 2). The weather conditions also modified the development of valerian rhizomes and roots. The plants exhibited the highest weight of underground parts in 2010, i.e. a year characterised by the highest precipitation rates during the vegetation season.

The average yield of valerian raw material was 2.76 t ha^{-1}, but irrespective of the variety, the highest raw material yield was obtained from plants grown from seedlings produced in the seedbed and transplanted in autumn (4.17 t ha^{-1}) (Table 1, Figure 2). A substantial role in determination of the yield size was ascribed to the plantation period. Both, direct seeding and seedling transplantation in autumn resulted higher raw material yield, compared with the spring establishment period. Using the method of spring seedling transplantation, better yields were obtained from the multi-cell tray seedlings than from those grown in the seedbed (Table 1). What is more, direct seeding into the field, both in autumn and spring, resulted in a significant decrease in the raw material yield. Similar to the other features described above, the genetic factor had a substantial impact on the raw material yield. On average, a few per cent lower yields of *Valerianae radix* were obtained in the case of the thin-rooted variety (‘Polka’) cultivation (with spring seed sowing as the only exception). Similarly to the other features described above, the weather conditions (in particular the rate and distribution of precipitation) had a substantial impact on the raw material yield. The lowest yields were obtained in 2009, i.e. a year with the lowest rainfall.

Content of active substances: The content of valerenic acid and essential oil in the roots and rhizomes varied significantly depending on the plantation establishment method and variety (Tables 3-4). In our study, the content of essential oil in the raw material harvested from each object was rather high and ranged from 0.71 to 1.11 ml·100 g^{-1} (Table 3), whereas the valerenic acid content ranged between 0.11 and 0.28% (Table 4). Significantly higher amounts of essential oil were detected in the raw material derived from plants grown using the direct seeding method than from the seedling-propagated plants. Over the years, the content of essential oils was modified by the genetic factor to a greater extent than by the plantation method. Generally, the thin-rooted variety was characterised by a higher content of essential oil and valerenic acid than the thick-rooted one. Over the years, the content of essential oils was modified by weather conditions to a greater extent than by the experimental factors. The warmest year 2009 proved to be the most favourable for synthesis of essential oil.

As far as valerenic acid is concerned, the highest content of this compound was noted in valerian roots obtained from direct seed sowing and autumn seedling transplantation than from spring transplantation (both seedlings produced in multi-cell trays and on seedbeds). While examining the variety as a variability factor, we found significant differences revealing an advantage of the thin-rooted plants of the ‘Polka’ variety. The same relationship was observed in the case of active substance accumulation in the valerian rhizomes; however, the valerenic acid content was considerably lower than that in the roots.

In the experiment, a positive correlation was found between the root diameter and weight and yields of the underground parts of the plants. Furthermore, a strong positive correlation was observed between the content of essential oils and valerenic acid in both the valerian roots and rhizomes, and at the same time a tendency to a decrease in the accumulation of active substances (particularly in the rhizomes) along with an increase in their raw material yields (Table 5).

Table 1. Morphological features of common valerian grown in central Europe (Poland) depending on the method of plantation establishment and variety (mean from 2009-2011)

Method of plantation establishment	Number of roots unit·plant^{-1}		Diameter of root mm	
	Lubelski	Polka	Lubelski	Polka
Autumn seed sowing in the field	132^{a†}±33.0¶	138^{a} ±4.6	2.90^{a} ±0.4	2.87^{a} ±0.28
Spring seed sowing in the field	112^{ab} ±16.1	109^{b} ±11.7	3.13^{b} ±0.52	2.96^{ab} ±0.36
Autumn seedling transplanting from the seedbed	140^{c} ±7.0	154^{c} ±13.5	3.82^{c} ±0.3	3.41^{c} ±0.42
Spring seedling transplanting from the seedbed	124^{b} ±20.1	146^{d} ±24.5	3.37^{d} ±0.12	3.00^{ab} ±0.39
Spring seedlings transplanting from multicell trays	143^{c} ±24.5	138^{a} ±18.0	3.19^{b} ±0.47	3.10^{b} ±0.27
LSD for:				
A – method of plantation establishment		***		**
B – variety		**		***
Interaction A × B		*		**

NS, *, **, *** – non- significant or significant at $P \leq 0.1$, 0.05 or 0.01; ¶ - standard deviation; † - different letters indicate significant difference between the means within column

Table 2. Air-dry weight of roots and rhizomes of common valerian grown in central Europe (Poland) (g plant^{-1}) - mean from 2009-2011

Method of plantation establishment	rhizomes		roots	
	Lubelski	Polka	Lubelski	Polka
Autumn seed sowing in the field	8.1^{a†} ±2.2¶	11.1^{a} ±4.6	25.1^{a} ±8.6	23.4^{a} ±5.7
Spring seed sowing in the field	6.0^{a} ±1.7	6.5^{a} ±1.1	21.4^{b} ±7.5	20.3^{a} ±5.5
Autumn seedling transplanting from the seedbed	17.6^{bc} ±3.9	18.3^{b} ±2.9	46.3^{c} ±10.2	42.9^{b} ±6.9
Spring seedling transplanting from the seedbed	8.6^{ad} ±2.4	8.6^{ac} ±2.5	31.0^{d} ±7.1	29.8^{c} ±5.4
Spring seedlings transplanting from multicell trays	12.3^{a} ±2.4	13.8^{a} ±2.2	33.5^{d} ±8.2	30.4^{c} ±7.2
LSD for:				
A – method of plantation establishment	***			**
B – variety	**			**
Interaction A × B	*			**

NS, *, **, *** – non-significant or significant at $P \leq 0.1$, 0.05 or 0.01; ¶ - standard deviation; † - different letters indicate significant difference between the means within column

Table 3. Content (ml·100 g^{-1}) of essential oil (EO) in roots and rhizomes of common valerian grown in central Europe (Poland) depending on method of plantation establishment and variety (mean from 2009-2011)

Method of plantation establishment	EO content in rhizomes		EO content in roots	
	Lubelski	Polka	Lubelski	Polka
Autumn seeds sowing in the field	0.83^{a†} ±0.25¶	0.95^{a} ±0.14	1.01^{a} ±0.24	0.92^{ab} ±0.12
Spring seeds sowing in the field	0.86^{a} ±0.1	0.89^{a} ±0.25	1.01^{a} ±0.14	0.96^{a} ±0.08
Autumn seedlings transplanting from the seedbed	0.75^{ab} ±0.13	0.89^{a} ±0.23	0.94^{ab} ±0.11	0.86^{b} ±0.23
Spring seedling transplanting from the seedbed	0.76^{ab} ±0.18	0.94^{a} ±0.11	0.88^{b} ±0.07	1.11^{a} ±0.2
Spring seedlings transplanting from multicell trays	0.71^{b} ±0.03	0.71^{b} ±0.19	0.90^{ab} ±0.16	0.92^{ab} ±0.08
LSD for:				
A – method of plantation establishment		*		**
B – variety		***		**
Interaction A × B		NS		*

NS, *, **, *** – non-significant or significant at $P \leq 0.1$, 0.05 or 0.01; ¶ - standard deviation; † - different letters indicate significant difference between the means within column

Table 4. Content (%) of valerenic acid (VA) in roots and rhizomes of common valerian grown in central Europe (Poland) depending on method of plantation establishment and variety (mean from 2009-2011)

Method of plantation establishment	VA content in rhizomes		VA content in roots	
	Lubelski	Polka	Lubelski	Polka
Autumn seed sowing in the field	0.16 [a†] ±0.06[¶]	0.18[a] ±0.1	0.23[a] ±0.06	0.23[a] ±0.05
Spring seed sowing in the field	0.17[a] ±0.30	0.19[a] ±0.01	0.25 [a] ±0.02	0.24[ab] ±0.03
Autumn seedling transplanting from the seedbed	0.15[a] ±0.06	0.17[a] ±0.07	0.21[ab] ±0.02	0.25[ab] ±0.03
Spring seedling transplanting from the seedbed	0.11[b] ±0.02	0.14[ab] ±0.06	0.16[b] ±0.02	0.28[b] ±0.02
Spring seedlings transplanting from multicell trays	0.11[b] ±0.03	0.13[b] ±0.06	0.16[b] ±0.03	0.23[a] ±0.04
LSD for:				
A – method of plantation establishment		**		**
B – variety		***		***
Interaction A × B		*		*

NS, *, **, *** – non-significant or significant at $P \leq 0.1$, 0.05 or 0.01; ¶ - standard deviation; † - different letters indicate significant difference between the means within column

Table 5. Correlation coefficient among the investigated traits in valerian roots

	Root diameter	Yield of roots and rhizomes	Air-dry weight of rhizomes	Air-dry weight of roots	EO in rhizomes	EO in roots	VA in rhizomes
Yield of roots and rhizomes	0.421***						
Air-dry weight of rhizomes	0.363**	0.910***					
Air-dry weight of roots	0.419**	0.984***	0.821***				
EO in rhizomes	0.137	-0.314*	-0.269	-0.316*			
EO in roots	-0.181	-0.115	-0.244	-0.051	0.309*		
VA in rhizomes	-0.196	-0.392**	-0.322*	-0.399**	0.552***	0.373**	
VA in roots	-0.319*	-0.076	-0.091	-0.067	0.111	0.488***	0.526***

*, **, *** – correlation significant at $P \leq 0.1$, 0.05 or 0.01, EO - essential oils content, VA – valerenic acid content

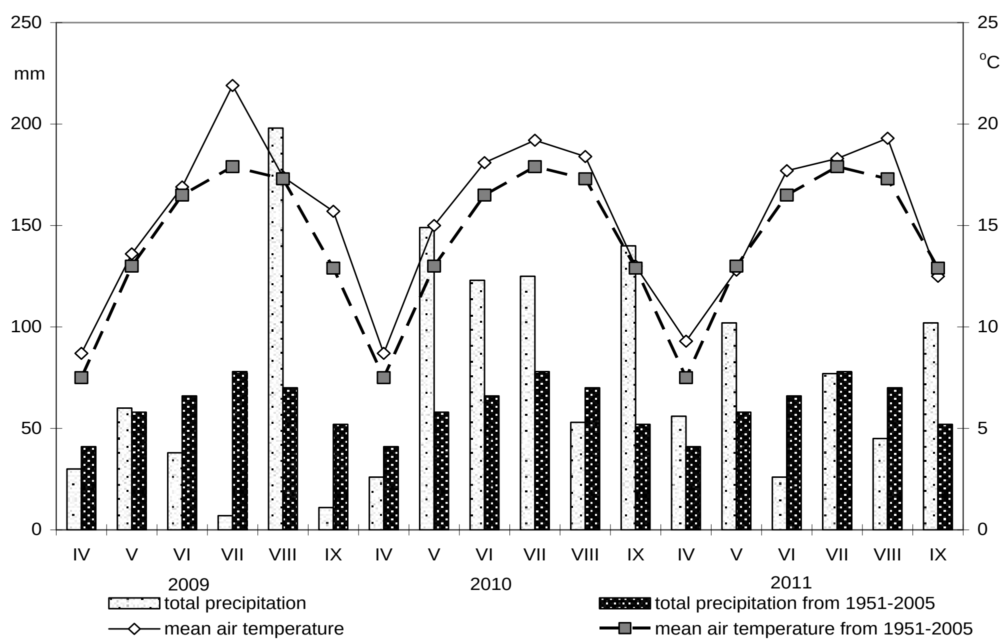

Figure 1. Average monthly air temperature and accumulated precipitation during 3 years of valerian cultivation (2009-2011).

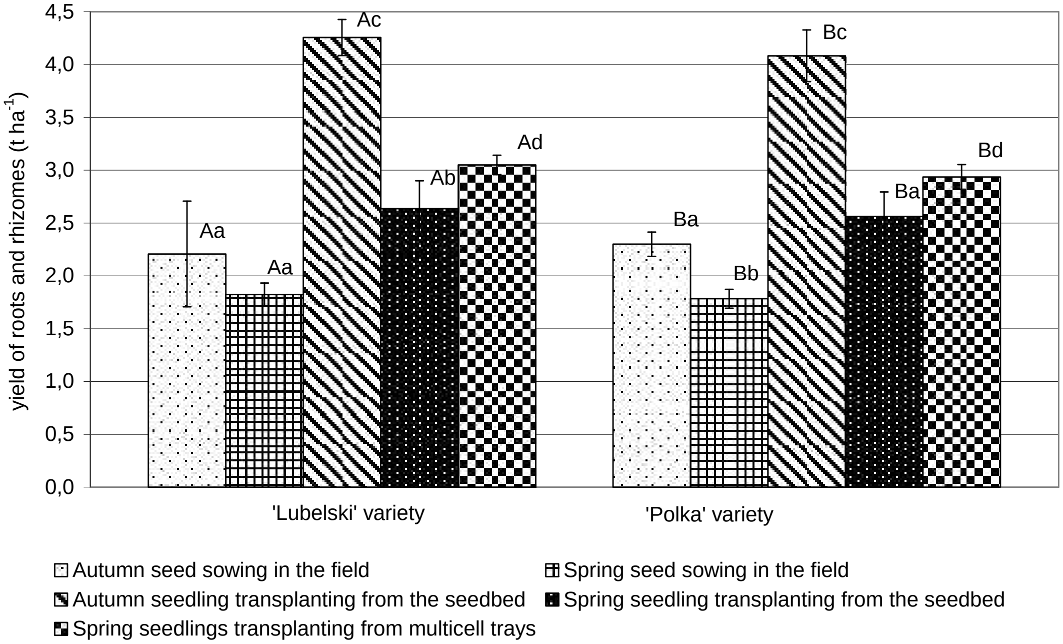

Figure 2. Common valerian yields of roots and rhizomes (t ha^{-1})
Vertical bars shows standard deviation, whereas different letters indicate significant difference between the means (uppercase superscripts – between varieties, lowercase superscripts – between plantation establishment methods)

DISCUSSION

The results of our investigations have shown that such traits of roots as their number and thickness depended not only on the variety but also on cultivation practice. ‘Lubelski’ variety was characterised by a smaller number of thicker and heavier roots than the ‘Polka’ variety. The size and weight of the underground parts of the common valerian plants were comparable to those obtained by Wills and Shohet (2003) and Seidler-Łożykowska *et al*. (2009), but higher than the values reported by Pop *et al*. (2010).

In literature, there is no information about the reaction of valerian to different plantation methods. Better developed underground parts of the plants were observed in the objects with seedling transplantation (both produced in multi-cells in spring and obtained on the seedbed and transplanted in autumn). In turn, direct seeding (particularly in spring) and traditional production of seedlings transplanted in spring yielded a significantly smaller number of thinner roots and lower amounts of raw material. Similar research on the marshmallow (Andruszczak and Wiśniewski, 2007) showed that cultivation of this species from seedlings produced in multi-cell trays contributed to formation of more branched roots with a larger diameter, compared to plants propagated by direct seeding. Consequently, a significant increase in yields was achieved in objects comprising plants propagated by seedlings. Similar relationships were reported by Kołodziej (2012) in the case of artichoke, whereas research carried out by Kołodziej and Najda (2007) proved that production of seedlings in multi-cell trays extended the period of growth and had a positive effect on raw material yields, particularly in species susceptible to low temperatures. Notably, regardless of whether the seeds were sown into the field or seedbed, establishment of plantations in autumn contributed to production of a higher number of thicker and heavier roots, compared with the spring period of plantation. This phenomenon could be explained by the fact that autumn seeding contributed to an early onset of vegetation growth in spring, which ensured higher yields than those obtained after the spring seeding.

The yield of valerian raw material ranged between 1.8 and 4.3 t ha^{-1}, which corresponded to the values reported in Moniuszko and Wiśniewski (2001) as well as Szczepanik and Wiśniewski (2009), but was lower than the yield reported by Morteza *et al*. (2010) and Dambrauskiene *et al*. (2010). The highest yields of roots and rhizomes were obtained from the thick-rooted variety grown from seedlings produced in the seedbed and transplanted in autumn. Generally, the plantation in autumn resulted in higher yields of underground parts than that in spring. The differences obtained in our experiment could be due to the longer vegetation period of plants produced in multi-cell trays or sown in the seedbeds and transplanted in autumn than in the case of the plantation established in the spring. On the other hand, better development of seedlings (both on the seedbed and in multi-cell trays) contributed to the higher raw material yields than those obtained in objects with direct seeding into the field. In the case of spring sowing, farmers usually have a problem with lower germination capacity of valerian seeds, which is the highest just after seed harvesting in August (Kołodziej, 2010).

This research was concentrated on the content of valerenic acid and essential oil as a measure of valerian quality. In common valerian roots, the content of essential oil ranged from 0.1 to 2 ml·100 g^{-1} (Raal *et al*., 2007; Seidler-Łożykowska *et al*., 2009; Morteza *et al*., 2010; Pop *et al*., 2010; Dambrauskiene *et al*. (2010)), while the valerenic acid content varies from 0.04% to 0.6% (Wills and Shohet, 2003; Hassan *et al.*, 2008; Seidler-Łożykowska *et al*., 2009). Such a large divergence might be related to differences in the age of the plant, its development stage, and growing conditions. According to the European Pharmacopoeia (2006), dried valerian roots should contain no less than 0.5 ml·100 g^{-1} of essential oil and 0.17% of valerenic acid. In our study, all herbal material contained the required amount of essential oil. Almost all the raw material samples obtained from valerian roots met these requirements, whereas that derived from the rhizomes only failed to meet them, likewise in the investigations carried out by Wills and Shohet (2003). A higher content of essential oil was observed in the raw material derived from plants grown using the direct seeding method than from the seedling-propagated plants. Similar results were obtained by Kołodziej and Najda (2007) and Andruszczak (2007) in an experiment on the lovage. In turn, the investigations on the lovage conducted by Rosłon *et al*. (2013) revealed a higher content of bioactive compounds in roots of plants grown from seedlings.

Lower yields of raw material that was difficult to clean during the harvest but at the same time exhibited a higher content of active substances were obtained from the thin-rooted variety (‘Polka’) plantations. Moreover, a positive correlation was found between the content of essential oil and valerenic acid, indicating that varieties with a higher content essential oil should be chosen for commercial culture. The higher content of essential oil and valerenic acid in the thin-rooted variety probably resulted from the fact that, although they could produce better developed and easily washable heavier roots with a higher diameter, the thick-rooted plants were simultaneously characterised by smaller root surface area. Thus, the number of essential oil reservoirs and, as a result, the content of active substances was lower. Contrarily, the thin-rooted plants produced a higher number of roots with a small diameter and higher surface area; therefore, they were characterised by a higher amount of cellular essential oil reservoirs and higher accumulation of active substances.

As far as valerenic acid is concerned, the highest content of this compound was noted in valerian roots obtained from direct seed sowing and from autumn seedling transplantation in comparison to spring transplanting (seedlings produced both in multi-cell trays and on seedbeds). It is worth stressing that the raw material from the last two objects does not meet the European Pharmacopoeia (2006) requirements. While examining the variety as a variability factor, we found significant differences revealing an advantage of thin-rooted plants of ‘Polka’ variety. The same relationship was observed in the case of active substance accumulation in valerian the rhizomes; however, the valerenic acid content was considerably lower than that in the roots. Generally, the quality of the raw material obtained from the rhizomes does not meet the European Pharmacopoeia (2006) requirements (with the exception of the objects grown with the Polka variety and direct seed sowing or autumn seedling transplantation).

Among the compared methods of common valerian propagation, seedling cultivation provided better conditions for plant growth and development than direct seeding; however, the therapeutically important valerenic acid content in the raw material produced in this way was significantly lower (especially in spring). In turn, the raw material derived from plants obtained via direct seeding was characterised by a significantly higher content of essential oil and valerenic acid and should be recommended in high quality valerian culture. In the case of direct seeding, the autumn period was more favourable for better development of the root system and higher yields of raw material characterised by high accumulation of active compounds. On the other hand, plants obtained from the seedlings transplanted in autumn produced the most abundant roots, which were additionally thicker than those in the other experimental objects. Consequently, they gave higher raw material yields, with a satisfactory content of active substances, thus this method of plantation could be used on a commercial scale. By spring planting, higher raw material yields were obtained from seedlings produced in multi-cell trays, which ensured better growth conditions and higher weight of the root system; however, the significantly lower amount of active substances eliminates such material from use in pharmaceutical industry.

In the experiment, a positive correlation was found between the content of essential oils and valerenic acid, both in the valerian roots and rhizomes, and tendency to a decrease in the accumulation of active substances along with an increase in their raw material yields. Our finding confirmed the investigations conducted by Seidler-Łożykowska *et al*. (2009) connected with the negative relationship between yielding and accumulation of active ingredients; however, but they did not find a correlation between the content of valerenic acid and essential oil.

A further advantage of this study was the finding on greater retention of valerenic acid in dried roots that had been separated from underground parts of valerian plants before drying. The rootlets were characterised by a higher concentration of valerenic acid than the rhizomes, which was in accordance with the findings reported by Wills and Shohet (2003). Therefore, they can be separated and sold as a higher quality product or that fraction can be used to improve the quality of a product that does not fulfil the requirements of the pharmaceutical industry.

REFERENCES

Andruszczak, S. (2007). The effect of the method of plantation establishment and harvesting time on some morphological features of plants and essential oil content in lovage roots (*Levisticum officinale* Koch.). Acta Sci. Pol., Hortorum Cultus 6 (1): 21–27.

Andruszczak, S. and J. Wiśniewski (2007). Growth and development of marshmallow (*Althea officinalis* L.) depending on the method of plantation establishment. Herba Pol. 53: 63-69.

Bos, R., H.J. Woerdenbag, H. Hendriks, J.H. Zwaving, P.A.De Smet, G. Tittel, H.V. Wikström, and J.J.C. Scheffer (1996). Analytical aspects of phytotherapeutic valerian preparations. Phytochem. Anal. 7: 143-151.

Circosta, C., R. De Pasquale, S. Samperi, A. Pino and F. Occhiuto (2007). Biological and analytical characterization of two extracts from *Valeriana officinalis.* J Ethnoph. 112: 361-367.

Dambrauskiene, E., V. Zalatorius and P. Viskelis (2010). Influence of growing methods on valerian root yield and quality. Sodininkyste ir Darzininkyste 29(4): 85-91.

European Pharmacopoeia V. 2006. European Directorate for the Quality of Medicines. Strasbourg: Council of Europe, 2667-2668.

Fernández, S., C. Wasowski, A.C. Paladini and M. Marder (2004). Sedative and sleep-enhancing properties of linarin, a flavonoid-isolated from *Valeriana officinalis*. Pharm. Bioch. Behav. 77(2): 399-404

Hassan, E., R. Tayeheh, T. Samaneh, B.S. Zeinalabedin, N. Vahid and Z. Mehdi (2008). Quantification of valerenic acid and its derivatives in some species of *Valeriana* L. and *Centranthus longiflorus* Steve. Asian J Plant Sci. 7(2): 195-200.

Kołodziej, B**.** (2010). Growing herbs. Grower's manual. Poznan: Polish Agricultural and Forestry Publishing, 450 p.

Kołodziej, B. (2012). Effects of irrigation and various plantation modalities on production and concentrations of caffeoylquinic acids and flavonoids of globe artichoke leaves (*Cynara scolymus* L.). Europ. J Hort. Sci. 77(1): 16-23.

Kołodziej, B. and A. Najda (2007). Plantation establishment methods in cultivation of chosen medicinal plants. Herba Pol. 53(3): 268-272.

Moniuszko, H. and J. Wiśniewski (2001). The effect of cultivation method and plat density on valerian (*Valeriana officinalis* L.) yielding and chemical composition. Annales UMCS, sec. E, Agric. 9: 107-112.

Morteza, E., G.A. Akbari, S.A. Sanavi and H.A. Farahani (2010). Determination of the vegetative and reproductive characteristics of valerian (*Valeriana officinalis* L.) under sowing dates and planting densities at Iran. J Med. Plant Res. 4(10): 857-861

Patoka, J. and J. Jakl (2010). Biomedically relevant chemical constituents of *Valeriana officinalis.* J. Appl. Biomem. 8: 11-18.

Pop, M.R., C. Sand, D. Bobiş, M.M. Antofie, H. Barbu, P.B. Pavel, L. Muntean and M. Savatti (2010). Studies concerning the production of volatile oil, rhizomes and roots, to different genotypes of *Valeriana officinalis* L. Anal. Univ. Oradea – Fasc. Biol. 17(2): 332-335.

Raal, A., A. Orav, E. Arak, T. Kailas and M. Müürisepp (2007). Variation in the composition of the essential oil of *Valeriana officinalis* L. roots from Estonia. Proc. Eston. Acad. Sci. Chem. 56(2): 67–74.

Rosłon, W., E. Osińska and A. Wajs-Bonikowska (2013). Effect of plantation establishment and raw material stabilization on the usefull traits of lovage leaves (*Levisticum officinale* Koch). Acta Sci. Pol., Hortorum Cultus 12(1): 141-155.

Seidler-Łożykowska, K., M. Baraniak and S. Mielcarek (2009). Content of essential oil and valerenic acids in valerian (*Valeriana offcinalis* L.) roots at the selected developmental phases. J Essen. Oil Res. 21(5): 413-416.

Szczepanik, M. and J. Wiśniewski (2009). Comparison of yield and qualitative characteristics of raw material of three cultivars of common valerian (*Valeriana officinalis* L.) cultivated from seedlings. Zesz. Nauk. Post. Nauk Roln. 542: 511-516.

Wills, R. and D. Shohet (2003). Production of high quality Australian valerian products. Rural Industries Research and Development Corporation Publ. No. 03/081, 39 p.